Laid to Rest

The Laboratory is cleaning house

and sending decades' worth of nuclear waste to a salt-encrusted grave.

THE BIG 18-WHEELER with its strange-looking cargo trailer rumbles down Pajarito Road and straight through the heart of Los Alamos National Laboratory's 36-square-mile campus, passing perhaps a half dozen technical areas, a few variegated meadows, and some pristine high-desert terrain before intersecting New Mexico Route 4, which serves as the Laboratory's eastern boundary. The truck's specialized trailer is one of several used by the Department of Energy (DOE) to transport transuranic nuclear waste, also known as TRU waste. Such waste consists of items, for example, lab coats and lab equipment, that have been contaminated with any of the radioactive elements heavier than uranium: primarily plutonium, neptunium, and americium. The loaded truck makes a left and continues its scheduled run to the Waste Isolation Pilot Plant (WIPP), some 300 miles distant in southeastern New Mexico.

WIPP is the nation's only licensed deep geologic repository for nuclear waste. When the truck arrives, its radioactive cargo will be inspected, loaded onto an elevator, and ferried 2150 feet underground, where a huge warren of tunnels and cavernous catacombs has been hogged out from the middle of a half-mile-deep bed of natural salt. The waste packages will be moved into an available room, set in place, and unceremoniously laid to rest.

It seems straightforward—gather waste, bury it underground—but this is a challenging business, disposing of TRU waste. Every step needs to be done correctly, or small problems can quickly become big ones. The route taken by the WIPP truck, for example, goes around Santa Fe (the state capital), through Roswell (the state's extraterrestrial capital), through numerous small western towns, and crosses miles of culturally and environmentally sensitive land. Any incident that would expose the public to even a minor amount of radiation would have major consequences.

Kathryn Johns-Hughes oversees the Laboratory's TRU Program, which as per agreement between the New Mexico State Environment Department (NMED) and the Department of Energy (DOE), aims to ship a total of 3706 cubic meters of accumulated TRU waste to WIPP by June 2014. It's a demanding goal. Unofficially, about 650 shipments will be needed to move that much material, a number that's on par with the total number of shipments made in the first 12 years that Los Alamos has been shipping waste to the repository.

But Johns-Hughes works with a world-class team of overachievers. They found ways to process the waste more efficiently, and the results have been remarkable.

"Our goal for the 2012 fiscal year was to make 184 shipments to WIPP," Johns-Hughes said. "We easily exceeded that and made 230, and we plan to make on the order of 300 shipments this fiscal year."

The accelerated pace was achieved without cutting corners or compromising safety or security, a priority that has been paramount since day one of operations. Indeed, in more than 1100 trips to WIPP, no truck has ever failed to reach its destination. There have been no accidents, no spills, no release of radiation of any kind.

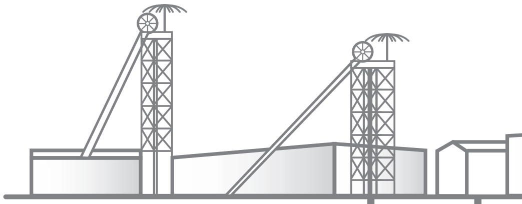
Transuranic (TRU) waste can be any item that has been contaminated with alpha-particle-emitting elements heavier than uranium—primarily plutonium, but also neptunium, americium, and curium. TRU waste is transported by truck to WIPP. The supersized steel containers on the truck bed are nearly indestructible, each capable of carrying 14 fifty-five-gallon steel drums of TRU waste.

"It's largely due to a strict adherence to procedures and a team that takes pride in its work," said Johns-Hughes about the sterling track record. "We ship nuclear waste. It's not a glamorous project, but it's a worthwhile one. We're proud to help Los Alamos clean up the past and have a sustainable future."

TRU Waste

The United States categorizes nuclear waste according to process, not level of radioactivity or hazard potential. High-level nuclear waste, for example, is fuel that has either been irradiated in a nuclear reactor or material generated from the reprocessing of that fuel. It consists of unfissioned uranium fuel, transuranic elements that were created from the uranium, and highly radioactive fission products. Low-level nuclear waste consists of items that have been contaminated as a result of exposure to radiation.

Los Alamos stores much of its TRU waste at an isolated site known as Area G. (Top) The long white structures are containment domes—metal framed, fire-resistant warehouses. (Bottom) About 20 percent of the Laboratory's TRU waste is packaged in steel barrels, awaiting transport to WIPP.

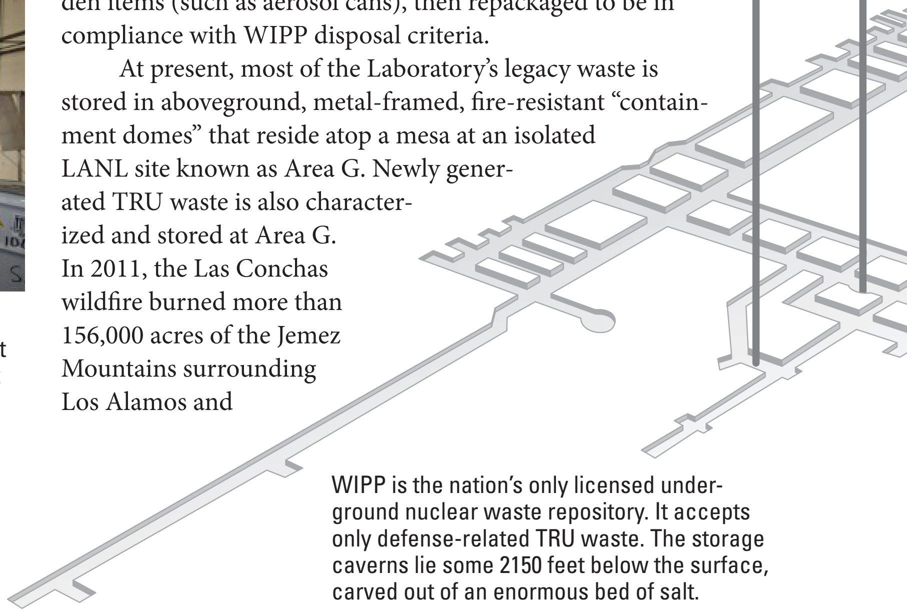


Transuranic waste is defined similarly to low-level waste, it being anything contaminated with the alpha-particle-emitting transuranic elements. The definition is so broad that a huge variety of products make up TRU waste: used protective clothing, tools, paper wipes, small containers, the various whatnots used to carry out plutonium research, as well as large and unwieldy items such as glove boxes, machinery, or even layers of soil. Regardless of the item, its radioactive content can range from very low to too hot to handle, the latter requiring remote handling.

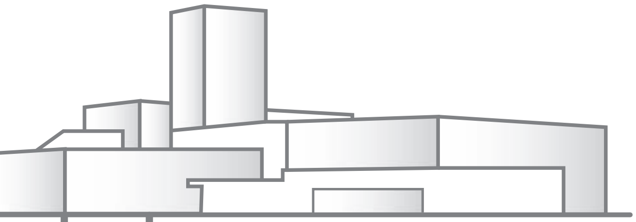
TRU waste continues to be generated at the Laboratory as a result of current research into plutonium and other transuranics. This newly generated waste is relatively straightforward to process, since workers know exactly what they are dealing with. The waste gets packaged in an appropriate container—say, a 55-gallon drum or a larger disposal container—with crews maintaining strict control over various limits, including the amount of radiation per type of storage container.

But part of the legacy of 70 years of weapons research and development are stores of TRU waste that were generated prior to 1994 (some of it like 40 years prior). This so-called legacy waste is not so straightforward to process. The decay of a transuranic element triggers a series of decays, each of which is typically accompanied by the emission of gamma rays. The decays and emissions will degrade plastics or paper goods, so waste containers that have been sealed for decades frequently have a buildup of hydrogen gas—a safety hazard—or an unknown breakdown of chemical constituents. Before being shipped to WIPP, each legacy container is assessed and, if necessary, vented. Also if necessary, containers may be opened, the waste extracted, sifted through to remove forbidden items (such as aerosol cans), then repackaged to be in compliance with WIPP disposal criteria.

At present, most of the Laboratory's legacy waste is stored in aboveground, metal-framed, fire-resistant "containment domes" that reside atop a mesa at an isolated LANL site known as Area G. Newly generated TRU waste is also characterized and stored at Area G. In 2011, the Las Conchas wildfire burned more than 156,000 acres of the Jemez Mountains surrounding Los Alamos and



WIPP is the nation's only licensed underground nuclear waste repository. It accepts only defense-related TRU waste. The storage caverns lie some 2150 feet below the surface, carved out of an enormous bed of salt.



came within 3.5 miles of Area G. It prompted the framework agreement between the DOE and NMED that resulted in Kathryn Johns-Hughes' dedicated team working very hard to remove 3706 cubic meters of TRU waste. Ultimately, the Laboratory plans to close Area G and to transfer TRU waste management capabilities to the to-be-built TRU Waste Facility. (See "Intelligent Design" on page 15.)

None of this happens unless WIPP is happening, so to speak, which it is, much to the delight of a Carlsbad community that has voiced strong public support for the repository. After 13 years of operations, WIPP has demonstrated an impressive fiscal and operational efficiency. And it all shakes out because of salt.

Any item contaminated with trace amounts of a transuranic element can be classified as TRU waste. This x-ray image, taken of a TRU waste storage container, reveals pipes and a sprinkler head from a discarded fire safety system.

WIPP and the Miracle of Salt

WIPP is carved out of an enormous layer of common salt (sodium chloride, NaCl) that formed when an inland sea evaporated approximately 250 million years ago. Termed bedded salt, (as opposed to domal salt, which is shaped like an enormous underground mushroom), it runs for hundreds of miles, from southern Texas and southeast New Mexico, through the Texas panhandle and all the way up to Colorado and Kansas. Such formations are common throughout the United States and the world and have been mined for millennia for table salt. Engineers have been able to tap into a wealth of information on how to mine salt efficiently and what to expect for WIPP's system of tunnels and rooms.

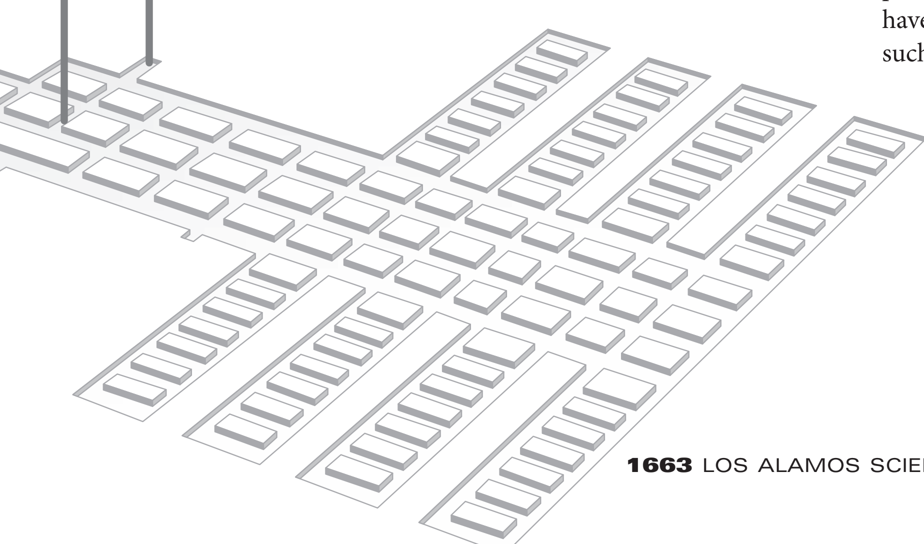
Given that the bedded salt formation has remained intact for hundreds of millions of years, the expectation is that it will continue to remain intact for many million more. That's good news for a repository that is intended to keep its radioactive contents isolated for millenia. Furthermore, the salt formation's existence is an indication that water is unable to penetrate into the undisturbed salt. Water is an overriding concern for a repository; it can corrode a waste container, dissolve the contents, and transport the radioactive material off site. But the salt's permeability to water is evidently low, or else much of the bedded salt would have dissolved over time. Its permeability is so low as to be unmeasurable using traditional hydrological and reservoir engineering methods.

Still, the property that makes salt a particularly favorable waste disposal medium is its ability to creep, or flow slowly. This unique mechanical behavior occurs in response to the pressure exerted by the rock overburden. One consequence is that fractures that open in the salt due to mining operations or earthquakes will, over time, heal as the salt creeps into the open space, and any cracks or fissures that could have served as conduits for water to enter the repository get sealed shut. The other consequence is that over time the salt should creep and flow around an emplaced waste container, sealing it in a waterproof, timeless tomb.

Hot Solution

WIPP's salt *is* creeping, as expected. It raises the possibility that a new repository carved out of bedded salt could serve as a disposal medium for materials that are prohibited from being buried at WIPP: namely, defense-related, high-level nuclear waste and spent fuel from commercial nuclear power plants. Of course, any new salt repository would have to be approved and licensed before it could accept such waste.

Ned Elkins is the Laboratory's Repository Science and Operations group leader. Stationed in Carlsbad, New Mexico, near the WIPP site, the group provides technical support to the DOE's Office of



Depending on the impurities embedded within it, the salt from WIPP can be anything from a reddish, relatively opaque rock to a clear crystal like the one shown here.

Environmental Management for nuclear issues and advises other institutions on how to technically achieve their goals, consistent with DOE objectives. Members of the group have already provided information to the DOE on the feasibility of a high-level nuclear waste repository in a subterranean bedded salt formation.

"High-level nuclear waste gives off substantial heat," said Elkins, "so you would have a heat source (the waste) sealed inside a waste package, surrounded by other hot waste packages, and they're all getting slowly enveloped by salt. Not surprisingly, there's little data about the integrated mechanical, hydrological, and chemical behavior of that system."

What is known is that salt is an excellent thermal conductor, and it's ability to conduct heat away from a source is approximately three to five times higher than other potential geologic media, such as crystalline rock or clay. This is a positive attribute, as the heat would be rapidly dissipated into the surrounding formation. A series of laboratory-scale experiments and a modeling effort has been proposed that will investigate the behavior of salt under high-heat conditions.

Elkins, however, argues that no amount of laboratory testing or modeling alone would be adequate to prove the performance of a nuclear waste repository, and that field tests should be an essential part of any licensing program. Field tests to investigate the properties of hot salt are planned and would take place in a remote part of WIPP known as the Salt Disposal Investigations Research Area, consisting of more than 8000 linear feet of newly excavated tunnels.

It's expected that the creep rate will increase with temperature, so the waste will get encased faster; but at very high temperatures, the salt may actually burst as tiny pockets of water trapped within the salt vaporize and expand. The results of both the laboratory and field experiments will be used to improve predictive models of the thermo-mechanical-hydrological behavior of the hot salt so that any future repository site can be expertly evaluated.

Whether a new repository will be built or not will be debated at the national, state, and local levels. In the meantime, WIPP will quietly go about its business, receiving shipment after shipment of TRU waste. It is, to date, a successful experiment in the proper disposition of nuclear waste and helps do what everyone wants to do: clean up, protect the public, and be responsible.

—Jay Schecker

Rocky Flats, the Cold War-era complex that manufactured plutonium triggers for nuclear weapons, was shut down in 1989 because its facilities, soil, and groundwater had become seriously contaminated with plutonium. More than 800 buildings were decontaminated and demolished, and the contaminated concrete was shipped to WIPP. Remediation of the soil, initially thought to be a monumental problem, was found to be tractable after a Los Alamos-led scientific team determined that the plutonium in the soil had formed hydrated plutonium dioxides, which adhere to soil particles. The information led to a much better understanding of how to remediate the site, namely by removing just the top 10–12 centimeters of soil. The soil remediation effort finished a year ahead of schedule, with a likely cost savings of billions of dollars.

Intelligent Design

Dan Vitaletti, TRU Waste Facility Design Manager, is clearly excited as he talks about the to-be-built TRU Waste Facility (TWF). Slated to open in 2015, the new facility will be part of a comprehensive, long-term strategy to consolidate hazardous and radioactive waste operations at the Laboratory into a smaller, more compact area. Currently, all TRU waste is stored and characterized at an isolated Laboratory site known as Area G, which has been used for waste disposal since 1957.

"We're going from 66 acres at Area G down to six acres," Vitaletti says, "but the facility will have superb capability to manage all newly generated TRU waste."

Vitaletti asks Brad Pulliam, design engineer, to bring up a drawing of the TWF on a computer. Instantly, the monitor displays a detailed, 3-D rendering of the facility, one of the many benefits of using Building Information Modeling (BIM) software to design the facility. The BIM software melds the tools of computer-aided design (CAD) with a powerful database. Anything having to do with the facility—blueprints, work orders, inventory lists, maintenance schedules—becomes integrated into an all-encompassing project model. It allows designers, contractors, and users alike to check out every aspect of the facility, from the layout of the ventilation system to the serial numbers of the supply closet keys.

Pulliam shifts the point-of-view and focuses on a large, warehouse-like building.

"Waste containers will be stored in enclosed buildings before they're shipped to WIPP," says Vitaletti. "We'll also validate and certify the containers for shipment."

"Now let's talk protection," he says, and he delves into describing several of the facility's enhanced protection features. Federal law requires that almost any type of potential hazard, accident, or possible insult to the facility be analyzed and controls to mitigate such insults be approved by the DOE. The Defense Nuclear Facility Safety Board and other governmental or independent entities scrutinize the entire safety analysis.

"The design of this facility was driven by the accident safety analysis," says Vitaletti. "For example, we needed to have roadside barriers that were strong enough to stop a large vehicle from entering the site. Currently, the TWF's barriers are designed to stop a 10,000-lb truck moving at 50 miles per hour, but we're looking to upgrade to a barrier that will stop a similarly moving 65,000-lb truck."

He continues: "The facility is protected by a seismic switch that will cut power in case of a seismic event, and by a dedicated fire suppression system in case of a fire. There's a minimum of 75 feet of clear space around the facility that affords us protection against wildfires. We even changed sites to get farther away from the Los Alamos airport to minimize the risk an airplane crashing into the facility."

Really?

"We designed this to be an enduring facility that will operate safely, securely, and effectively for the foreseeable future," says Vitaletti. "So yeah, Really!"

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